N87-17807

SPACE STATION SUPPORT OF MANNED MARS MISSIONS

Alan C. Holt
Space Station Customer Integration Office/PD4
NASA Johnson Space Center, TX

ABSTRACT

The assembly of a manned Mars interplanetary spacecraft in low Earth orbit can be best accomplished with the support of the Space Station. Station payload requirements for microgravity environments of 10^{-3}g and pointing stability requirements of less than 1 arc second could mean that the spacecraft may have to be assembled at a station-keeping position about 100 meters or more away from the Station. In addition to the assembly of large modules and connective structures, the manned Mars mission assembly tasks may include the connection of power, fluid, and data lines and the handling and activation of components for chemical or nuclear power and propulsion systems. These assembly tasks wilL require the use of advanced automation and robotics in addition to Orbital Maneuvering Vehicle and EVA crew support. Advanced development programs for the Space Station, including on-orbit demonstrations, could also be used to support manned Mars mission technology objectives. Follow-on studies should be conducted to identify Space Station activities which could be enhanced or expanded in scope (without significant cost and schedule impact) to help resolve key technical and scientific questions relating to manned Mars missions.

INTRODUCTION

The assembly of a manned Mars spacecraft will occur where long duration crew and robotics support will be available to insure that the spacecraft can be safely assembled and that the spacecraft systems are functioning as expected. The Space Station is the only planned facility capable of supporting these assembly and checkout operations in a cost-effective manner.

While the manned Mars mission (and Lunar missions) are being included in the Space Station mission data base, they can not be considered as drivers for the initial orbital capability (IOC) of the Station. However, they are encompassed by the Station's growth phase and therefore will be considered in the establishment of IOC interfaces (scar) which support growth requirements. Thus it is important that Phase B Space

Station definition studies consider the potential impacts of manned Mars missions on growth accommodation provisions. It is equally important that the planners of manned Mars spacecraft and missions be aware of the capabilities and limitations of Space Station support for assembly, departure, return, and refurbishment phases of manned Mars missions.

MARS SPACECRAFT ASSEMBLY SUPPORT

Space Station Motion and Disturbance Dynamics

The IOC Space Station will be designed to accommodate payloads which will require a 10^{-5}g microgravity environment and which will attempt to achieve sub-arcsecond pointing stability through the use of station (coarse) and user-provided fine pointing and stability systems. Meeting these payload requirements will be a substantial challenge for the Space Station.

Gravity gradient disturbances and drag effects on the Space Station will practically limit the microgravity environment achievable to 10^{-6}g. Many normal Station activities including crew movements may have to be restricted during critical payload operations' phases to achieve the Station's microgravity goal. Activities such as Orbiter berthing (10^{-2}g), crew wall pushoff (10^{-3}g), and crew console operations (10^{-4}g) will have to be timelined around or restricted during certain materials processing payload operations and solar and stellar observations if adequate isolation techniques are not developed by IOC.

The growth Space Station operations may not be as restrictive if most of the materials processing payloads and experiments move onto co-orbiting platforms where much lower microgravity environments may be achievable. Alternatively, the Space Station may be replicated, providing a Station for microgravity and sub-arcsecond payloads and a Station which is dedicated to servicing and transportation node functions.

However, it is possible that combination of budget constraints and mission times would dictate that only the IOC Space Station will be available for initial support of a Mars Mission. As one planning option, we should assume that the IOC Station must be able to support a manned Mars mission and determine how it can best be used to support Mars spacecraft assembly and checkout.

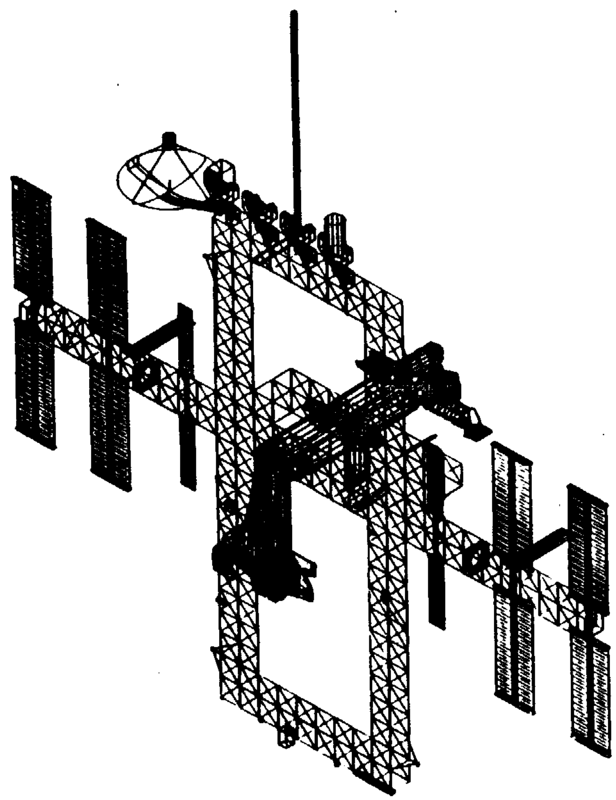
Attached and Station-Keeping Assembly and Checkout

The initial Mars spacecraft element to be brought up would likely be a Mission Module with life support systems, data management systems, communications and telemetry systems, habitability systems, and a power distribution and storage system. This module could be temporarily berthed at the Station, where the systems could be activated and checked out by the Station crew. The Mission Module would likely be common with Space Station modules. If the common module has a length of 49.5 feet (one of the Station options under study), it would fill a Shuttle cargo bay.

During this checkout phase of one day or so, micro-g and some solar and stellar operations could be suspended for a short time, if necessary. Once the systems have been activated and checked out, the Mission Module could be attached to the Station in a quiescent mode until additional spacecraft elements are brought up. Alternatively, if the Mission Module substantially alters the location of the Station's center of gravity to the detriment of materials processing payloads, the Mission Module could be moved to a position 100 meters or more from the Station for station-keeping operations. (See Figure 1) A temporary (or built-in) attitude control system package could be attached and activated. A contingency power system, probably of the same type used for the Space Station, could be erected until the primary power system is brought up and attached in the next Shuttle flight. If the next Shuttle can be scheduled within a week, then the suspension of certain Space Station materials processing activities for that period of time could probably be negotiated successfully.

Four to six Shuttle flights might be needed to bring up and assemble the power and propulsion elements. For a chemical propulsion system, additional flights would be needed to attach the required propellent tankage. An additional three or four flights could be used to bring up the second Mission Module, the Mars Excursion Module (landing vehicle), the module outfitting equipment (if required) and other scientific equipment. The second Mission Module would be checked out at the Space Station in a manner similar to the first module. The Mars Excursion Module could also undergo preliminary checks while attached to the

SERVICING PLATFORM AND MOBILE ROBOTS FOR MANNED MARS MISSION SPACECRAFT ASSEMBLY



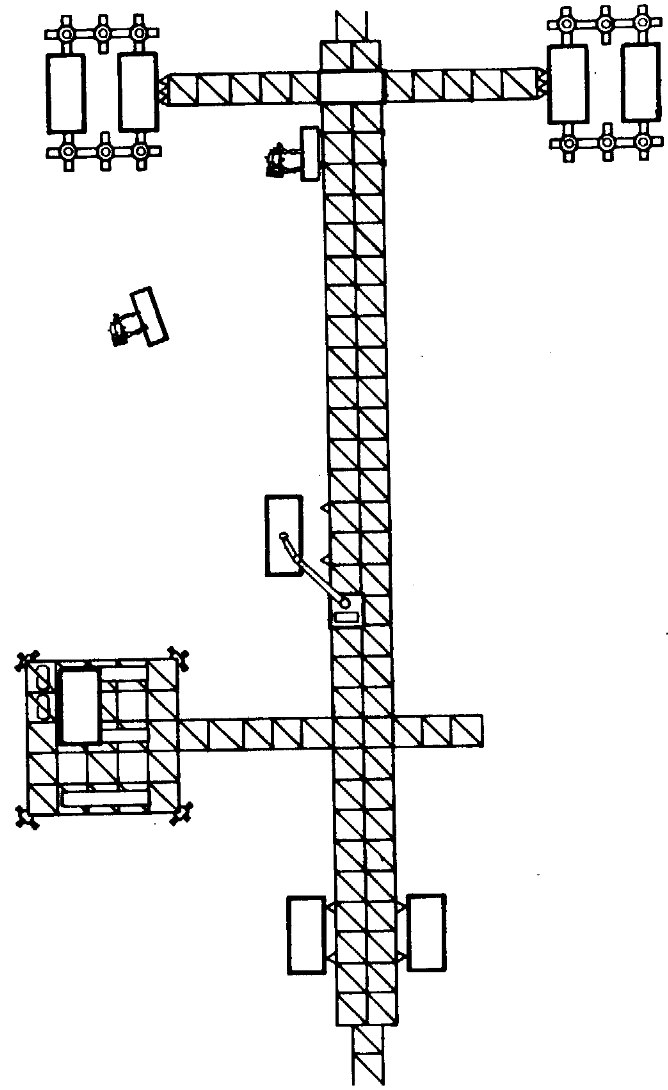


FIGURE 1

Station or could be checked out from a Mission Module after attachment to the Mars spacecraft.

The Space Station modules may be launched without internal outfitting, to allow utilization of larger modules and/or achieve higher orbit deployments. If the same procedure is required for the Mars Mission Modules, outfitting could be accomplished while the modules are attached to the Station for the initial systems activation and checkout. Tradeoffs between potential vibration disturbances of Space Station payloads and the advances of outfitting activities which could take several days would have to be made. With good planning and adherence to mutual schedules, this should not be any more of a problem for the Space Station than a normal Orbiter logistics visit.

Activation and check out of the power system and propulsion and attitude control systems would be conducted, in part, remotely from the Station. Activation and checkout would be completed by crewman in the Mission Module. For a nuclear propulsion system, remote activation and extensive checkout of the power and propulsion systems would be required to insure a safe environment prior to sending a crewperson to the Mission Module for final checks. Once the manned Mars spacecraft has been assembled, integrated systems tests would be conducted. These tests would include the exercise of contingency procedures and possible active tests of propulsion systems.

AUTOMATION AND ROBOTICS

Automation and robotics will play an important role in supporting many Space Station and platform activities. For servicing of the platforms and freeflyers at the Station, an Orbital Maneuvering System with a "smart front end" and the Module Remote System will almost certainly be required. In addition, the servicing area at the Station may require additional automation and possibly some robotics to assist with the connection of fuel lines and refueling operations, to replace modular elements, to resupply cryogen systems, and to assist with repairs. These activities will probably be conducted with substantial EVA crew and Mobile Remote Manipulator support. The availability of automated and robotic elements will reduce the amount of EVA required and the risks to the EVA crew associated with fluid transfers and possible spills.

In addition, some advanced robotic systems, such as a mobile robot, will be studied and may be available for use in the assembly of large space structures, for the handling of nuclear components and to assist in certain laboratory module operations. Congress has mandated that the Space Station program be used to support the development of automation and robotics which extends state-of-the-art applications and benefits the U.S. industry. Dependent upon the amount of Space Station funding that is available for IOC and Growth phase advanced development, a multi-purpose mobile robot could emerge from the program and would be available to support the assembly of a manned Mars spacecraft, inflight Mars spacecraft maintenance and repairs, and Mars surface activities.

A mobile robot coupled with an OMV with a "smart front end" could be used to handle active nuclear elements and conduct operations in areas with relatively high radiation levels which would help enable a more extensive use of nuclear power systems in space. These operations have their parallel in potential industrial co-orbiting platforms, which may require the use of nuclear power and nuclear electric propulsion.

SPACE STATION RENDEZVOUS AND SPACECRAFT MAINTENANCE

Parking Location for Mars Spacecraft

For a spacecraft which departs from and returns to the Space Station the natural parking location would be in an orbit co-planar with the Space Station. If a nuclear power system is used, nuclear electric propulsion would be the best choice to keep the spacecraft relatively close to the Space Station. The nuclear powered spacecraft could be brought into a station-keeping position on its own power or with the assistance of the OMV for maintenance and additions such as the replacement of an engine, a replacement for the Mars Excursion Module left on the surface and on Mars orbit, and outfitting of the Mission Modules and Logistics Modules for Mars base construction activities.

A non-nuclear powered spacecraft may have to be allowed to drift away from an optimum orbital location to reduce the amount of attitude control propellent required to maintain station-keeping. For maintenance activities, the attitude control and propulsion systems (partly re-supplied after the initial return to the Station) could be used to bring the spacecraft to the vicinity of the Station where the OMV can be used to assist in the final positioning.

If a manned Orbital Transfer Vehicle is available, other options could be considered, including a parking location of the Mars spacecraft in a much higher orbit to which a crew could be ferried. However, unless a GEO Space Station or an advanced robotics mobile servicing facility is available, maintenance and reassembly of a Mars spacecraft may be costly and time consuming in a higher orbit.

Space Station Isolation Quarters or Clean Room

The IOC Space Station reference configuration does not currently have isolation quarters or a clean room. Requirements for Mars and comet sample return missions using the Space Station as a transportation mode may result in the development of a clean room capability or the addition of a special module for this purpose. However, it is possible that provisions for the prevention of crew exposure to toxic gases or materials could result in the capability to close off or isolate a Laboratory Module. This module or a combination Habitation/Laboratory Module (a possible Space Station study option) could be used for temporary crew isolation, if necessary.

Spacecraft Maintenance and Reassembly

Spacecraft maintenance and reassembly activities in preparation for a return to Mars would be expected to utilize the same capabilities used in the initial spacecraft assembly activities. Resupply of propellent could take place by accessing Station propellent storage facilities, by use of a co-orbiting, mobile propellent storage facility (potential Space Station growth phase option), or by the use of Shuttle fuel tankers. Spacecraft propellent resupply operations near active or used nuclear systems would require more extensive use of mobile robotics and OMV activities to avoid crew exposure to radiation substantially higher than background radiation.

SPACE STATION/MARS SPACECRAFT SYSTEMS COMMONALITY

Space Station Common Module and Logistics Module use for Mars Spacecraft

A Space Station Common Module is being developed for the Habitability and Logistics Modules. These modules will have certain common infrastructure such as primary structure, power, data and thermal subsystems and interfaces. The module control and display and working area layouts are expected to be oriented along the long axis of the module, which would optimize the amount of usable space for artificial gravity orientations of Mars spacecraft Mission Modules.

While no spare modules are being planned for the IOC Station, growth phase requirements will mean that the capability to produce additional Common Modules will have to be maintained. For a manned Mars mission in the post 2000 period, it should be possible to place orders for Common Modules from the Space Station contractors and take advantage of IOC module experience in the outfitting of the Mars spacecraft modules.

The use of the Space Station Logistics Module should be considered for storage of certain consumables and for later mission use in the transfer of Mars base construction materials to the surface with an advanced Mars Excursion Module. Alternatively, unmanned missions could be used to land Mars base construction materials on the surface prior to first and/or subsequent missions.

COMMON DEVELOPMENT OF ADVANCED POWER, ATTITUDE CONTROL, AND PROPULSION SYSTEMS

The Space Station IOC power system is expected to be designed such that the transition to solar dynamic or nuclear power systems will cause a minimum of system reconfiguration. As a goal, the power distribution subsystem would have a standard interface with the power generation subsystem which would not change. In the process of developing power systems for the growth Space Station, design features could be considered which would enhance the ease of integrating these systems into a manned Mars spacecraft and a Mars base.

Resistojets and nuclear electric propulsion will be investigated for use on the IOC and growth Stations and platforms. Their performance parameters could be influenced (within certain cost/schedule constraints) by the requirements of manned Mars spacecraft activities. Advanced studies or development funding associated with manned Mars missions could be used to actively support the consideration of Mars mission requirements in Space Station definition and advanced development activities.

SPACE STATION TECHNOLOGY DEVELOPMENT AND EXPERIMENT SUPPORT

There are a number of advanced development activities and technology and scientific experiments being planned for the Space Station and Shuttle which will support some of the key technical and scientific areas of concern for manned Mars missions. A close interaction with these activities and their results by manned Mars mission interests is needed. For some activities, a more direct infusion of manned Mars mission concerns should be attempted.

If the National Commission on Space and/or NASA Headquarters chooses to outline some broad, long-range goals which include lunar and manned Mars missions, it should be possible to begin influencing ongoing Station definition studies, advanced development studies and technology in support of future programs. In Space Station and other government studies and research, the following areas, among others, should be investigated:

1. Long Term Weightlessness Effects and Countermeasures.
2. Progress Towards a Closed Environmental Control and Life Support System.
3. Development of Cryogenic Propellent Storage, Handling, Gauging, and Transfer Capabilities.
4. Large Space Structure Assembly and Construction Techniques
5. Plant Growth Techniques for Zero-G
6. Nuclear power and Propulsion Studies
7. Laser Communications and Positioning Systems
8. Automation and Robotics Studies
9. Inflight Training Techniques and Capabilities
10. Advanced Shielding Techniques

CONTINUING STUDY ACITIVITIES

In the area of Space Station program support of manned Mars mission studies and planning, each of the following activities should be pursued:

1. Identify specific Space Station design decisions which should be influenced by manned Mars mission planning - determine approach for inserting relevant information into the decision process.
2. Identify the advanced development activities which should be enhanced to support or otherwise consider manned Mars mission activities.
3. Determine the design studies and operations issues which must be addressed to support the assembly and maintenance of nuclear or other large power systems in space.
4. Identify specific technology demonstration activities which can support both the growth phase of the Space Station program

and manned Mars missions (such as mobile robots, advanced, active or passive shielding, closed environmental control systems, holographic imaging systems for onboard training, advanced propulsion systems, and artificial intelligence systems) and determine an approach for establishing joint study activities.

REFERENCES

1. Space Station Mission Requirements, Space Station Customer Integration Office, Code PD, NASA JSC, 1985.
2. Automation and Robotics Implementation Plan, Systems Engineering and Integration (S.E.&I.) Office, Code PB, NASA JSC, 1985.
3. Space Station Systems Requirements, Space Station Systems Engineering and Integration (S.E.&I.) Office, Code PB, NASA JSC, 1985.
4. Customer Integration Automation and Robitics Priorities (draft form), Customer Integration Office, Code PD4, NASA JSC, 1985.